PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 16 June 2000 (16.06.00)	
International application No. PCT/JP99/05210	**Applicant's or agent's file reference** S98406/PCT
International filing date (day/month/year) 22 September 1999 (22.09.99)	**Priority date** (day/month/year) 22 September 1998 (22.09.98)
Applicant MOLSEN, Henning et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

19 April 2000 (19.04.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Henrik Nyberg Telephone No.: (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

ational Application No
PCT/JP 99/05210

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/1335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	EP 0 487 359 A (SHARP KK) 27 May 1992 (1992-05-27) page 5, line 18-47 page 6, line 17-40 page 8, line 12 -page 9, line 55; figure 10 ---	1-3,6,7, 11,13,14 4,5,8-10
Y A	US 5 699 137 A (KISHIMOTO KEIKO) 16 December 1997 (1997-12-16) column 1, line 46 -column 2, line 53 column 7, line 1-21 column 9, line 15-65; claim 1; figure 1 ---	1-3,6,7, 11,13,14 4,5,8-10
Y A	EP 0 699 938 A (SHARP KK) 6 March 1996 (1996-03-06) column 3, line 1 -column 4, line 1 column 6, line 1-33; figures 6,8,13 --- -/--	3,7,13 4,5,8,9

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 April 2000	05.05.00
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Wahl, M

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 4 315 258 A (MONAHAN MICHAEL A ET AL) 9 February 1982 (1982-02-09) cited in the application column 3, line 23 -column 5, line 20; figures 2,3	1,2,6, 11, 14-17,19 12
Y A	GB 2 101 347 A (GEN ELECTRIC) 12 January 1983 (1983-01-12) page 1, line 71 -page 3, line 107	1,2,6, 11, 14-17,19 12
Y	US 5 510 915 A (GE XIAOQIN ET AL) 23 April 1996 (1996-04-23) column 5, line 54 -column 8, line 34; figures 6,9	15-17,19
A	EP 0 342 835 A (STC PLC) 23 November 1989 (1989-11-23) column 6, line 46 -column 7, line 13; figure 3	15-19

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP 99/05210

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. [X] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[X] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/JP 99/05210

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-14

   Transflective liquid crystal display comprising
   - a liquid crystal cell with front and rear substrates,
   - front and rear polarisers,
   - front and rear retarders, and
   - a light source.

2. Claims: 15-23

   Transflective liquid crystal display having a plurality of pixels each provided with a light filter; means for addressing and switching each pixel; a flashing backlight comprising a plurality of sequentially flashing light sources, and a partially reflecting mirror.

INTERNATIONAL SEARCH REPORT

mation on patent family members

ational Application No
PCT/JP 99/05210

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0487359 A	27-05-1992	JP 4194820 A	14-07-1992
		DE 69125101 D	17-04-1997
		DE 69125101 T	28-08-1997
		US 5249071 A	28-09-1993
US 5699137 A	16-12-1997	JP 9101515 A	15-04-1997
EP 0699938 A	06-03-1996	GB 2292814 A	06-03-1996
		EP 0864907 A	16-09-1998
		JP 8076148 A	22-03-1996
US 4315258 A	09-02-1982	NONE	
GB 2101347 A	12-01-1983	US 4398805 A	16-08-1983
		CA 1174345 A	11-09-1984
		DE 3224523 A	27-01-1983
		FR 2509074 A	07-01-1983
		HK 101785 A	03-01-1986
		JP 1626085 C	18-11-1991
		JP 2054530 B	21-11-1990
		JP 58024122 A	14-02-1983
		SG 83685 G	18-07-1986
US 5510915 A	23-04-1996	EP 0774132 A	21-05-1997
		JP 10508951 T	02-09-1998
		WO 9604585 A	15-02-1996
EP 0342835 A	23-11-1989	GB 2218842 A	22-11-1989
		JP 2064595 A	05-03-1990

REC'D 21 FEB 2001
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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference S98406/PCT	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/JP99/05210	International filing date *(day/month/year)* 22/09/1999	Priority date *(day/month/year)* 22/09/1998
International Patent Classification (IPC) or national classification and IPC G02F1/1335		
Applicant SHARP KABUSHIKI KAISHA et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 9 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of ~~28~~ 20 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☒ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand 19/04/2000	Date of completion of this report 15.12.00
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Wahl, M Telephone No. +49 89 2399 2684

Form PCT/IPEA/409 (cover sheet) (January 1994)

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:

Description, pages:

4,6,7,13-17	as originally filed			
1,1bis,2,3,3bis, 5,5bis,8,9,9bis, 10,10bis,11,11bis, 12	as received on	14/08/2000	with letter of	10/08/2000

Claims, No.:

1-11,13-23, 25-36	as received on	02/11/2000	with letter of	30/10/2000

Drawings, sheets:

1/12,3/12,5/12,8/12-10/12, 12/12		as originally filed		
2/12,4/12,6/12,7/12, 11/12	as received on	14/08/2000	with letter of	10/08/2000

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

☐ the description,	pages:	
☒ the claims,	Nos.:	12, 24
☐ the drawings,	sheets:	

5. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)
   see separate sheet

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☒ paid additional fees.

   ☐ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:
   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims 1-11, 13-23, 25-36
	No:	Claims
Inventive step (IS)	Yes:	Claims 1-11, 13, 14, 18, 20-23, 25, 27-36
	No:	Claims 15-17, 19, 26
Industrial applicability (IA)	Yes:	Claims 1-11, 13-23, 25-33
	No:	Claims

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item I
Basis of the report

1). The following amendments extend beyond the contents of the originally filed disclosure and have therefore not been taken into account in this report:

- the lower limit of 50 nm for the retardation range of the front quarterwave plate as defined in claim 6;
- the surface director orientation angle -20° as specified on page 8, line 30; page 9, line 24; and shown in Figs. 2, 4, and 6;
- the preferred twist angle range for the LC layer between 60° and 80° as mentioned on page 9, line 3;
- the design wavelength and features of the liquid crystal material as specified on page 10, lines 4-7;
- the retardation value of the front quarterwave plate of 150 nm as described in page 11, line 23, and page 12, line 29;

Re Item IV
Lack of unity of invention

The International Examining Authority found two (groups of) inventions in this international application, as follows:-

1. Claims: 1-14

   Transflective liquid crystal display comprising
   - a liquid crystal cell with front and rear substrates having a plurality of pixels,
   - front and rear polarisers,
   - front and rear retarders, and
   - a light source, and
   - a partially reflective/transmissive rear electrode.

2. Claims: 15-23

   Transflective liquid crystal display having
   - a plurality of pixels each provided with a light filter,

- means for addressing and switching each pixel,
- a flashing backlight with a plurality of sequentially flashing light sources, and
- a partially reflecting mirror between the liquid crystal and the backlight.

The common features of these "inventions" are

- a transflective liquid crystal display comprising a plurality of pixels, a light source and a partially reflective/transmissive optical element between the liquid crystal and the backlight.

Such a combination of features is well known in the art (see e.g. US-A-4 315 258) and therefore not novel.

The most relevant prior art documents for both inventions cited in the Search Report are the similar documents EP-A-0 487 359 and US-A-5 699 137.
In view of these documents, the special technical features of the first "invention" are related to the arrangement of rear and front retarders, which each comprise a halfwave and a quarterwave plate, with respect to the liquid crystal cell and to each other.
The special technical features of the second "invention" are related to the switchable pixels having color filters and the three flashing light sources.
These special technical features of both "inventions" are not so linked as to form a common novel and inventive concept.

Hence, the present application suffers from a lack of unity (Art. 34(3), Rule 13 PCT).

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1). The most relevant prior art document for the first invention is EP-A-0 487 359 (D1; see Fig. 10) which discloses a liquid crystal display comprising a liquid crystal (8) divided into a plurality of pixels and disposed between a front substrate (2) and rear substrate (3), a front polariser (9) and a rear polariser (10), a front retarder (11,12) and a rear retarder (13,14).
The subject matter of present claim 1 differs from D1 in that a light source is

located behind the rear polariser (10) and that the rear electrode is partially reflective/transmissive. While it is generally known in the art, e.g. from Fig. 2 of US-A-4 315 258 (D4) or from Fig. 1b of GB-A-2 101 347 (D5) to provide such backlight sources and partially reflective/transmissive mirrors behind LCD displays and EP-A-0 699 938 (=:D3) discloses an LCD display (Fig. 1) with adjacent rear electrode layer (26) and reflecting (non-transmissive!) layer (24), no hint could be found in the available prior art to combine this mirror and the rear electrode in order to form the presently claimed partially reflective/transmissive rear electrode. The invention thus provides an efficient transflective liquid crystal display which can be used with reflected ambient light as well as transmitted backlight.

The subject matter of independent claim 1 and the further embodiments defined in dependent claims 2-11, 13 and 14 are regarded as being novel and involving an inventive step and therefore meet the requirements of Art. 33(2) and (3) PCT. (This also applies to claims 25-36 insofar as they depend on claims 1-11, 13 or 14.)

2). However, the present application does not meet the requirements of Art. 33(3) PCT, because the subject matter of claims 15-17, 19, and 26 does not involve an inventive step.
US-A-5 510 915 (=:D6) discloses an active matrix liquid crystal display (see Fig. 9) comprising a plurality of sequentially flashing backlight sources (903). Lines 61-65 of column 6 further refer to colour filters associated with each pixel. Although line 12 of column 7 mentions that in such a display "colour filter is no(t) needed", the skilled person would nevertheless conclude that a colour filter could in principle be used in the display. Furthermore, from US-A-4 315 258 (=:D4) as well as GB-A-2 101 347 (=:D5) the person skilled in the art learns how to use a partially transmissive mirror (16 in D4, 30 in D5) in order to obtain a transflective display. Introducing such a partially transmissive mirror into the display of D6 would therefore result in a transflective display as defined in present claims 15-17.
Moreover, using LEDs as illumination light sources is well established in the art such that the subject matter of claim 19 is not regarded as involving an inventive step.
The transflective mirror (16) of D4 is about 50% transmissive (see Fig. 3) as specified in present claim 26.

Since D6 is concerned with a scattering liquid crystal display (e.g. PDLCD) no polarising effects appear and hence, polarisers or retarders are not needed therby rendering the subject matter of claims 18 and 23 non-obvious. Assuming that the lacking antecedent of the features defined in claims 28-36 (see objection 1(c) under item VIII) were solved by an additional separate introduction of these features, the subject matter of (clarified) claims 28-36 could in principle be regarded as novel and inventive.
Furthermore, none of the available prior art documents hints towards a colour filter having a varying level of absorption across its area or having a transparent region as specified in claims 20-22 and 27. This also applies to the partially transmissive/ reflective mirror having gaps or holes defined in claim 25.

3). The industrial applicability of the claimed transflective display is obvious (Art. 33(4) PCT).

Re Item VII
Certain defects in the international application

1). Although independent claims 1 and 15 are drafted in the two-part form, the features
- the liquid crystal is divided into a plurality of pixels, and
- the backlight comprises a plurality of sequentially flashing light sources,

are incorrectly placed in the characterising portions of claim 1 and claim 15, respectively, as they are disclosed in documents D1 and D6, respectively, in combination with the features placed in the respective preamble (Rule 6.3(b) PCT).
On the other hand, the definition of the partially reflective mirror in claim 15 should have been in the characterising portion instead of the preamble.

Re Item VIII
Certain observations on the international application

1). The application does not meet the requirements of Art. 6 PCT, because the claims are not clear in the following respects:-

(a) Claims 4, 5, 8, and 9 do not meet the requirements of Article 6 PCT in that the matter for which protection is sought is not clearly defined. The following functional statements do not enable the skilled person to determine which technical features are necessary to perform the stated functions:

> the retardation values of the front/rear quarterwave plate and the liquid crystal layer should be such that in one state circularly polarised light and in another state linearly polarized light is produces after a single pass.

Since the claims are silent on any mutual orientation of these elements or on the polarisation state of the light incident thereon they do not provide a sufficient and unambiguous definition of the claimed subject matter.

(b) It would appear that the reference to claim 6 in dependent claim 14 should have been corrected to claim 7, since only the latter introduces the rear halfwave plate and quarterwave plate which are further specified in claim 14.

(c) Claims 28 and 29 depend on any one of claims 1-27 and refer to said front and rear polarisers which, however, are not defined in claims 15-22 and 25-27.

An analogous objection applies to claim 30-33, each being dependent on claims 1-29, with respect to the nematic LC, which is not defined in any of the preceding claims, and the front and rear retarders, which cannot be found in claims 15-22 and 25-29. The objection with respect to the nematic LC also applies to claims 34 and 36. Analogously, the red, green and blue voltage levels referred to in claim 35 are not defined in any of the preceding claims.

Consequently, the subject matter of claims 30-36 is obscure and indefinite.

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G02F 1/1335

A2

(11) International Publication Number: WO 00/17707

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(21) International Application Number: PCT/JP99/05210

(22) International Filing Date: 22 September 1999 (22.09.99)

(30) Priority Data:
9820516.4 22 September 1998 (22.09.98) GB

22 Mar 01 30 mths

(71) Applicant (*for all designated States except US*): SHARP KABUSHIKI KAISHA [JP/JP]; 22–22, Nagaike–cho, Abeno–ku, Osaka–shi, Osaka 545–8522 (JP).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): MOLSEN, Henning [DE/GB]; 39 Helen Road, Oxford OX2 0DF (GB). TILLIN, Martin, David [GB/GB]; 11 Summer Fields, Abingdon, Oxfordshire OX14 2PG (GB).

(74) Agent: YAMAMOTO, Shusaku; Crystal Tower, 15th floor, 2–27, Shiromi 1–chome, Chuo–ku, Osaka–shi, Osaka 540–6015 (JP).

(81) Designated States: JP, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

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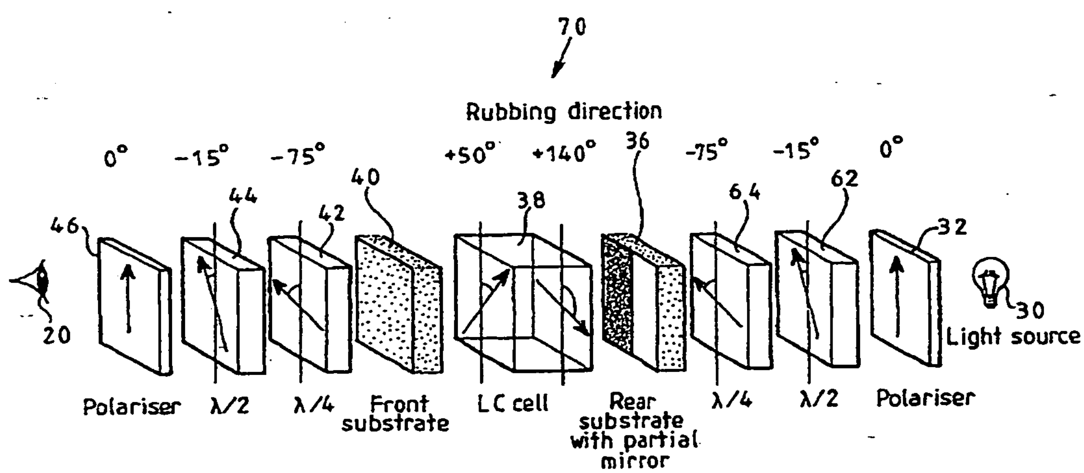
Without international search report and to be republished upon receipt of that report.

(54) Title: TRANSFLECTIVE LIQUID CRYSTAL DISPLAYS



(57) Abstract

A transflective liquid crystal display (70) comprises a liquid crystal cell (38) disposed between a front substrate (40) and a rear substrate (36), a front polariser (46) located in front of the front substrate (40) and a rear polariser (32) located behind the rear substrate (36), a front retarder (42, 44) located between the front substrate (40) and the front polariser (46), a rear retarder (62, 64) located between the rear substrate (36) and the rear polariser (32), and a light source (30) located behind the rear polariser (32). A transflective display having a number of differently coloured sequentially flashing backlights is also provided.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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DESCRIPTION

Transflective Liquid Crystal Displays

TECHNICAL FIELD

The invention relates to transflective liquid crystal displays, which rely for their operation on reflection of ambient light, and transmission of light from a backlight in the case of a low ambient light level.

BACKGROUND ART

European Patent Publication No. 0,840,160 A2 describes a Pancharatnam-type achromatic (ie. independent of frequency/colour) reflective liquid crystal display (LCD) using a twisted nematic liquid crystal (LC) layer as part of a switchable achromatic retarder.

British Patent Application No. 9806566.7 describes an improved retarder combination for an achromatic fixed retarder and twisted nematic (TN) LC used in high resolution thin film transistor (HR-TFT) displays, which reduces threshold voltage and chromaticity and improves contrast.

S. Fujiwara et al. "Proceedings of the Fourth International Display Workshops", Nagoya 1997, (IDW'97), p.879 describes a reflective LCD using an achromatic fixed retarder between a linear polariser and a twisted nematic LC. This is used in the HR-TFT LCD product produced by Sharp.

Solutions for converting linear polarised light to circular polarised light by a twisted nematic layer with respect to the LC parameters retardation, twist and alignment orientation can be found in Beynon et al., Proceedings of the International Display research Conference, 1997 L34.

US Patent No. 5,361,151 (Sonehara) describes a transflective LCD comprising a TN-LC layer, an internal or external semi-reflector, and chromatic retardation plates between the LC and the front and rear linear polariser.

US Patent No. 4,093,356 (J. E. Bigelow) describes a transflective liquid crystal display capable of presenting viewable indicia to an observer positioned at the front thereof,

which is responsive to either reflection of incident ambient light entering into the display from the front thereof, or transmission of light from a source behind the display, and which utilises a reflective display of the type having a nematic liquid crystal host-guest dichroic dye cell backed by a quarterwave plate and partially reflective, partially transmissive transflector member, in conjunction with a linear polariser and a second quarterwave plate arranged between the backlighting source and the partially transmissive member.

In such a guest-host cell, the dichroic dye is regarded as a guest in the liquid crystal, because the orientation of the dichroic dye molecules simply follows that of the LC molecules. The dye molecules are generally transparent when viewed along their long axes, and opaque (ie. they absorb visible light) when viewed perpendicular to their long axes, and are hence referred to as dichroic. Consequently, by applying a voltage to the LC cell, the degree of absorption in the cell can be controlled, and the cell is therefore sometimes referred to as operating in an absorption mode.

The rear quarterwave plate is used to compensate for the front quarterwave plate so that linear polarised light impinges on the guest-host liquid crystal (GH-LC).

US Patent No. 4,315,258 describes a visual display which has an increased readout capability due to its operation in a transflective mode. A source of ambient light and light for radiation through the display from the back together assure the increased readout capability. Previously, ambient light would degrade or wash-out the display making it nearly impossible for monitoring personnel to decipher alphanumeric or pictoral displays due to the decreased contrast. A pair of linear polarizers sandwich a twisted nematic liquid crystal and have their polarisation axes either parallel or mutually orthogonally disposed so that the crystal presents bright or dark areas in response to applied potentials. Because a partially transmitting mirror is interposed between the sandwiched liquid crystal and the radiating light source, the ambient light augments the radiated light to enhance the visual display.

It should be understood that, throughout this specification, references to retardation values should be understood as effective retardation values, taking into account the twist angle of the retarder. A twisted birefringent structure (such as a TNLC) has a retardation of thickness x birefringence for a particular wavelength. However, it effects a retardation which is lower or higher depending on the twist angle.

DISCLOSURE OF INVENTION

According to a first aspect of the invention there is provided a transflective liquid crystal display comprising a liquid crystal cell disposed between a front substrate and a rear substrate, a front polariser located in front of the front substrate and a rear polariser located behind the rear substrate, a front retarder located between the front substrate and the front polariser, a rear retarder located between the rear substrate and the rear polariser, and a light source located behind the rear polariser.

This allows the display to benefit from backlighting in low ambient light conditions and high contrast while still providing the benefits of an achromatic reflective display.

The front retarder may be an achromatic combination retarder.

The front retarder may comprise a front halfwave plate and a front quarterwave plate.

The front quarterwave plate may have a retardation of between 0nm and 250nm.

The front halfwave plate may have a retardation of between 200nm and 360nm.

The rear retarder may comprise a rear quarterwave plate.

The rear quarterwave plate may have a retardation of between 100nm and 180nm, and preferably of substantially 135 nm.

The rear substrate may be provided with a partially reflective and partially transmissive mirror.

The liquid crystal cell may be provided with a rear electrode, which is partially reflective and partially transmissive.

The rear retarder may further comprise a rear halfwave plate.

The rear halfwave plate may have a retardation of between 200nm and 360nm.

The rear halfwave plate may be located between the rear quarterwave plate and the rear polariser.

In order to use the same LC profile and thickness and the same operating mode (normally white) for reflective and transmissive modes of operation, the backlight can be manipulated first by a linear polariser followed by a quarter wave plate at 45° to the polarisation or absorption direction.

The invention broadens the usability of reflective LCDs by incorporating a backlight. This is achieved without major alteration to the existing HR-TFT fabrication process. As compared with front lighting systems the contrast ratio of the LCD using a backlight is not reduced. Although the transmission may be only 50% of the ideal value this is not critical to the readability of the LCD as the backlight will only be operated at low ambient light levels. The invention can also operate in normally black mode either in both transmission and reflection or transmission by changing the azimuth angle of both polarisers by 45° in the same direction.

The process flow to manufacture the internal reflector in the HR-TFT requires only one additional step. To secure uniform electric fields the etched window in the aluminium can be sputter-coated with indium tin oxide (ITO) in a self-aligning process. Surplus ITO on the photoresist used to pattern the aluminium mirror can be removed during the photoresist development or removal/strip. Multiple windows can be randomly distributed over the pixel to avoid diffraction.

Alternatively, the reflective layers can be thinned to an extent that it becomes partially transmissive to a predetermined value over the whole or part of the pixel electrode.

According to a second aspect of the invention, there is provided a transflective display comprising a liquid crystal divided into a plurality of pixels, addressing means for addressing each pixel and switching each pixel between different states resulting in different levels of transmission of light through the display, a flashing backlight located behind the liquid crystal, and a partially reflective mirror located between the liquid crystal and the backlight for both reflecting ambient light back through the liquid crystal and allowing transmission of light from the backlight through the liquid crystal, wherein each pixel is provided with a light filter, and wherein the backlight comprises a plurality of sequentially flashing light sources.

In one embodiment, of the invention, each light filter is a colour light filter, and said sequentially flashing light sources are of different colours.

Said liquid crystal may be part of an active matrix display.

In one embodiment, the liquid crystal forms a Pi or optically compensated birefringent (OCB) cell.

In a further embodiment, each light source is a light emitting diode (LED).

Each colour filter may provide a varying level of absorption across its area.

Each colour filter may have a transparent region.

This provides the advantage of ensuring that a greater amount of light from each light source can pass through every colour filter.

In this case, said liquid crystal may be provided with a plurality of partially reflective electrodes each having a light transmissive area, and each transmissive area may be optically aligned with a transparent region of one of said colour filters.

The transflective display of the second aspect of the invention may also have any or all of the features of the transflective display of the first aspect of the invention.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be more particularly described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows the arrangement described in US Patent No. 4,093,356 (mentioned above), which uses a quarterwave plate between a rear polariser and a reflector in a transflective GH LCD;

Figure 2 is a schematic view of a transflective LCD according to a first embodiment of the invention;

Figure 3 shows the results of modelling the LC electrooptic response of the embodiment of Figure 2;

Figure 3a shows the results of modelling the LC electrooptic response of the embodiment of Figure 2, but using crossed polarisers.

Figure 4 is a schematic view of a transflective LCD according to a second embodiment of this invention;

Figure 5 shows the results of modelling the LC electrooptic response of the embodiment of Figure 4;

Figure 6 is a schematic view of a transflective LCD according to a third embodiment of this invention.

Figure 7 shows the results of modelling the LC electrooptic response of the embodiment of Figure 6;

Figure 7a shows the results of modelling the LC electrooptic response of the embodiment of Figure 6, but using crossed polarisers;

Figure 8 is a schematic view of a transflective LCD according to a fourth embodiment of this invention.

Figure 9 shows the results of modelling the LC electrooptic response of the embodiment of Figure 8;

Figure 10 is a schematic diagram of the prior art pixellated reflective LCD with internal reflectors described in the Fujiwara reference mentioned above;

Figure 11 is a schematic diagram of a pixellated transflective LCD with internal reflectors and a transmission window in accordance with the invention.

Figure 12 shows a transflective LCD using a Pi or OCB cell, which is an embodiment of a second aspect of the invention;

Figure 13 shows the results of modelling the LC electrooptic response of the embodiment of Figure 12; and

Figure 14 shows the results of modelling of the LC electrooptic response of the embodiment of Figure 12, and shows the wavelength dependence of the electrooptic response for transmission and reflection in both the switched and unswitched states.

BEST MODE FOR CARRYING OUT THE INVENTION

The prior art transflective guest-host (GH) LCD 2 shown in Figure 1 comprises a light source 4, linear polariser 6, first quarterwave plate 8, partially transmissive mirror 10, second quarterwave plate 12, rear substrate 14, guest-host liquid crystal (GH-LC) cell 16, and front substrate 18.

The quarterwave plates (or retarders) 8 and 12 and the linear polariser 6 are formed from stretched polymer films. The GH-LC cell 16 contains a dichroic dye, the

molecules of which are oriented by the LC molecules in order to control the degree of absorption of the cell. The cell thus operates in an absorption mode. The GH-LC cell 16 is pixellated, with each pixel being controlled by a pair of electrodes (not shown) in known manner.

The display 2 is viewed from the position of the viewer 20. The light reaching the viewer 20 from the display is a combination of light from the light source 4 and (usually white) ambient light reflected by the partially reflective mirror 10. It is for this reason that the display is referred to as transflective, because it operates on the basis of both transmission and reflection.

The first embodiment of the invention, shown in Figure 2, is a transflective liquid crystal display 28 comprising a light source 30, a rear polariser 32, rear quarterwave plate 34, rear substrate 36, liquid crystal cell 38, front substrate 40, front quarterwave plate 42, front halfwave plate 44, and front polariser 46. The location of the viewer 20 is also indicated in Figure 2.

The arrangement of components of the display 28 from the front polariser 46 to the rear substrate 36 (inclusive) is known from the Fujiwara reference mentioned above, except that the rear substrate 36 of the display 28 is provided with a partially reflecting (and partially transmitting) mirror (not shown separately) instead of a fully reflecting mirror.

Figure 2 also indicates for each of the retarders 34, 42 and 44, the angle that the slow axis of the retarder makes with respect to the angle of the absorption axes of the two polarisers 32 and 46 (which are parallel, and defined as 0 degrees). These angles are -45°, -75° and -15° respectively. In addition, the angles at which the LC molecules are aligned by alignment layers (not shown) at the surfaces 48 and 50 of the LC cell 38 are also indicated in Figure 2. The surface director orientations (SDOs) are +50° and +140°, respectively. The term "surface director orientation" as used herein is defined as the orientation of the LC director at an alignment surface projected onto the plane of the alignment surface of the LC layer, so that the SDO is the orientation which the LC

director would have in the absence of any surface pretilt. Also, the SDO is equivalent to (SDO $\pm \pi$). The twist of the LC layer may be between 30° and 100°.

The two transparent parallel substrates 36 and 40 are each coated on the inside surfaces 52 and 54 with a patterned conductor/electrode (not shown) for addressing the LC cell 38, with the rear electrode being patterned and partially transparent and partially reflecting. The ratio of transmission to reflection of the rear conductor/electrode may be 1:1 or any other pre-determined value according to the designated purpose of the transflective display 28. The electrodes are coated with alignment means and hold the nematic LC cell 38 continuously switchable between an effective retardation in the reflecting bright state of 80nm to 200nm, and preferably 135nm, and in the dark state of 50nm to 0nm, and preferably close to 0nm. The nematic LC may be twisted by surface alignment and/or chiral doping.

The outer sides of the substrates 36 and 40 are clad by the transparent retardation films 34, 42 and 44. The front halfwave retarder 44 has a retardation $d\Delta n$ of substantially 270nm and the front quarterwave retarder 42 has a retardation $d\Delta n$ of substantially 133 nm, where d represents the thickness of the retarder film, and Δn represents the difference between the two refractive indices of the retarder film. The front quarterwave retarder 42 has its slow axis substantially parallel or normal to the bisetrix (ie. half the angle) of the (twist or) surface alignment directions of the nematic LC cell 38. (The angle -75° shown in Figure 2 is equivalent to +95° (ie. 75°+95°=180°), which lies half way between the SDOs + 50° and + 140° of the LC cell 38.). The two front retarders 42 and 44 form an achromatic combination retarder. The rear retarder 34 has a retardation $d\Delta n$ of substantially 133nm. The absorption or polarisation axis of the rear polariser 32 is at 45 degrees to the slow axis of the rear retardation film 34. The LC cell 38 may be MJ 96539 (Merck Japan), the retardation films 34, 42 and 44 of Nitto's NRZ range, and the polarisers 32 and 46 of Nitto's NPF range.

The bisetrix, or bisector, as used herein is the direction which bisects the smaller included angle between two directions. The bisetrix is also perpendicular to the optical axis of the device.

Figure 3 shows the results of computer modelling of the electrooptic response of the embodiment of Figure 2. The modelling was carried out assuming a standardised D65 light source for reflected and transmitted light in the wavelength range of 380 to 780 nm. The graph of Figure 3 shows voltage (applied to a pixel of the LC cell 38) against transmission and reflection in arbitrary units. The transmission results are shown by curve 56, and the reflection results by curve 58. For the reflection results a 0.1 micron aluminium mirror is assumed, and for the transmission results the mirror was removed.

When no voltage is applied, both the transmission and reflection are high, and the display thus operates in a "normally white mode". The rear quarterwave plate 34 is necessary in order to ensure that the transmission curve 56 is the correct way around. Without the quarterwave plate 34 the transmission curve 56 would be low at zero volts and high at 5 volts. It will be seen from Figure 3 that even at 4 or 5 volts there is still some residual transmission and reflection, which prevents the pixel from becoming fully dark. The embodiments discussed below seek to provide an improved contrast between the light and dark states.

Figure 3a shows the results of modelling the LC electrooptic response of the embodiment of Figure 2, but using crossed polarisers instead of parallel polarisers. That is, to produce the results of Figure 3a, the last two components (ie. the quarterwave plate 34 and polariser 32) are rotated through 90° compared to the arrangement shown in Figure 2. This results in a better (ie. darker) dark state for the transmission curve 56. The reflection curve is again labelled 58.

Figure 4 shows a second embodiment of the invention, which is a transflective display 60 providing reduced residual transmission in the dark state. Components which are the same as those of the first embodiment of Figure 2 are given the same reference numerals. The display of Figure 4 differs from that of Figure 2 in that the rear quarterwave plate 34 is replaced by a rear halfwave plate 62 and a rear quarterwave plate 64, which have slow axes at -15° and -75° respectively with respect to the absorption axes of the two polarisers 32 and 46. As shown by Figure 4, the components thus exhibit a degree of symmetry about the central LC cell 38. The combination of the

rear halfwave plate and rear quarterwave plate improves the achromaticity of the transmission mode.

The effective retardation of the nematic LC cell 38 is continuously switchable between about 135nm and 0nm in the same way as in the embodiment of Figure 2. The two front retarders 42 and 44 function together as an achromatic combination retarder, and the two rear retarders 62 and 64 also function together as an achromatic combination retarder. The retardation films can again be of Nitto's NRZ range.

Figure 5 shows the results of computer modelling of the electrooptic response of the embodiment of Figure 4. The transmission results are shown by curve 66, and the reflection results by curve 68. The assumptions mentioned above in relation to the graph of Figure 3 apply equally to the Figure 5. As shown by Figure 5, the embodiment of Figure 4 produces a slight reduction in the residual transmission (at around 4 to 5 volts) compared with the embodiment of Figure 2.

Figure 6 shows a third embodiment of the invention, which is a transflective display 70 providing both significantly reduced residual transmission and significantly reduced residual reflection. The components are essentially the same as those of the embodiment of Figure 4, and the same reference numerals are therefore used. However, the display 70 differs from that of Figure 4 in that the thickness of the front quarterwave plate (retarder) 42 is increased so that it has a retardation $d\Delta n$ of substantially 143 nm.

The front and rear quarterwave plates 42 and 64 have their slow axes substantially normal to the bisetrix of the surface director orientations of the nematic LC cell 38. The two front retarders 42 and 44, and the two rear retarders 62 and 64, each form an achromatic combination retarder. The front achromatic combination retarder is modified to compensate for the residual retardation of the LC cell at finite voltages. The retardation of quarterwave plate 42 is increased when the slow axis of each quarterwave plate is normal to the bisetrix of the SDOs of the nematic LC cell 38. Alternatively, if the slow axes of the quarterwave plates 42 and 64 are parallel to the bisetrix of the SDOs of the nematic LC cell 38. the retardation of quarterwave plate 42 needs to be decreased. The retardation films can again be of Nitto's NRZ range.

Figure 7 shows the results of computer modelling of the electrooptic response of the embodiment of Figure 6. The transmission results are shown by curve 72, and the reflection results by curve 74. The assumptions mentioned above in relation to the graph of Figure 3 apply equally to the Figure 7. As shown by Figure 7, the embodiment of Figure 6 produces a significant reduction in both the residual transmission and the residual reflection in the dark state (at around 4 to 5 volts) compared with the previous embodiments.

This improvement comes about because the increased thickness of the quarterwave plate 42 compensates for the residual retardation caused by the fact that those liquid crystal molecules in the LC cell 38 which lie close to the alignment layers (not shown separately) remain "fixed" in position when the LC cell 38 is switched by application of an external voltage.

Figure 7a uses the same reference numbers as Figure 7, and shows an improved (ie. darker) dark state for the transmission curve 56, achieved by rotating the last three components (ie. 32, 62 and 64) of Figure 6 through 90°, so that the polarisers 32 and 46 are crossed.

Figure 8 shows a fourth embodiment of the invention. The components of the transflective display 100 are essentially the same as those of the embodiments of Figures 4 and 6, and the same reference numerals are therefore used for components which are the same. However, the nematic LC cell 38 of Figures 4 and 6 is replaced by a hybrid aligned nematic (HAN) LC cell 102. The cell 102 used is LC MJ96539 produced by Merck, Japan and has antiparallel surface director orientation with surface pretilt of 2° and 88° and a retardation of substantially 137.5 nm. The orientations and retardations of the other components are given in Figure 8. The front substrate 40 also functions as a colour filter plate. The retardation of the front quarterwave plate 42 is changed to 151nm compared to 143nm for the TN cell.

Figure 9 shows the results of computer modelling of the electrooptic response of the embodiment of Figure 8. The transmission results are shown by curve 104, and the reflection results by curve 106.

Figure 9a uses the same reference numbers as Figure 9, and shows an improved (ie. darker) dark state for the transmission curve 104, achieved by rotating the last three components (ie. 32, 62 and 64) of Figure 8 through 90°, so that the polarisers 32 and 46 are crossed.

In any of the embodiments of the invention the partially reflective (and partially transmissive) mirror (not shown separately) provided on the rear substrate 36 can be either a mirror containing a number of gaps or holes, or a continuous mirror which is transparent to a predetermined value of say between 10% and 90%.

Figure 10 shows the layout of the prior art reflective LCD 76 described in the paper by S. Fujiwara mentioned above. From top to bottom, the display 76 comprises a polariser 78, one or more retardation films 80, micro colour filters 82, a front substrate 84, a liquid crystal layer 86 (represented schematically by liquid crystal molecules 87, reflective electrodes 88 controlled by thin film transistor (TFT) elements 90, and a rear substrate 92. Three colour filters 82, representing red, blue and green, are shown in Figure 10, each covering two reflective electrodes 88. Each electrode 88 corresponds to a subpixel. Figure 10 thus shows two pixels, each comprising three subpixels having red, blue and green filters. The liquid crystal molecules 87 located under the green filter 82 are shown switched, whereas the other liquid crystal molecules 87 are shown unswitched.

Figure 11 shows the layout of a transflective LCD in accordance with the invention. Where components correspond to those in Figure 10 the same reference numerals are used. The arrangement of Figure 11 differs from that of Figure 10 by the addition of one or more retardation films 92, a rear polariser 94, and a backlight 96. In addition the reflecting electrodes 88 are made partially transmissive by providing the electrodes 88

with apertures 98. As an alternative, the electrodes 88 can be made of a continuous partially transmissive material.

In any embodiment the red, green and blue voltage levels can be individually adjusted for transmission, transflective or reflection modes. The transmission/reflection against voltage curve is wavelength dependent and can be different between the reflective and the transmissive mode. Hence data voltages must be adjusted according to the mode used.

Each micro colour filter 82 can have areas of different absorption to achieve the best colour balance/saturation for transmission and reflection modes.

The invention can use LC modes switching substantially in the plane of the LC cell, so-called in-plane switching modes, found for example in ferroelectric, antiferroelectric and some nematic LC modes. The invention can also use out-of-plane switching modes, and is not limited to twisted nematics. For example, surface switching LC modes can be used.

Retardation values, twist angles, and other orientation angles given for the embodiments described above are examples only.

Embodiments of a second aspect of the invention will now be described.

Figure 12 shows a transfective LCD 100 which is capable of time sequential colour illumination. Components which are the same as those in Figure 8 are given the same reference numerals. The transflective LCD 100 comprises: three flashing LEDs, which are red 102, green 104 and blue 106, a rear polariser 32, a rear halfwave plate 62, a rear quarterwave plate 108, a rear substrate 36 provided with a partially reflecting mirror, a Pi or OCB cell 110 formed from the LC material TL203 made by Merck, a front substrate 40 provided with colour filters, a front quarterwave plate 112, a front halfwave plate 44 and a front polariser 46. The front quarterwave plate 112 has a retardation of 214nm. The increased retardation of the front quarterwave plate 112 is required to

compensate for the larger residual retardation of the Pi cell at finite voltages compared to the HAN and TN cell.

The angles which the slow axes of the retarders 62, 108, 112 and 44 make with respect to the absorption axes of the two polarisers 32 and 46 (defined as 0 degrees) are indicated in Figure 12, together with the retardation values of the retarders. Figure 12 also shows that the Pi cell 110 has zero twist.

The embodiment of Figure 12 also makes use of micro colour filters 82, as shown in Figure 11. When the ambient light level is low, the transflective LCD 100 switches (either automatically or manually) to a time sequential transmission mode in which the red, green and blue LEDs 102, 104 and 106 flash in turn. The pixels of the Pi cell 110 are addressed for each flash. This is why it is desirable to use a Pi cell rather than a TN LC cell, because a Pi cell can be switched more quickly.

It is possible to address the pixels of the Pi cell 110 in different ways. In the simplest case, when the green LED 104 is flashed, only the pixels with green micro colour filters 82 are switched on, and the other pixels are switched off (ie. to a zero transmission state).

However, if the micro colour filters 82 are sufficiently wide band, then each colour filter 82 will let through some light of each other colour. For example, the green filters which let through some red and blue light. In this case, it is possible to make use of all of the pixels for all of the coloured LEDs, provided that the transmission characteristics of the micro colour filters 82 are taken into account when addressing the pixels. In this way it is possible to increase both the light throughput and the resolution of the display, because when the green LED 104 is flashed, for example, light can pass through pixels having micro colour filters 82 of any colour.

It is still necessary to retain the micro colour filters 82 to allow the LCD to operate in a reflective mode when the ambient light level is sufficiently high. and therefore reduce the power consumption of the device.

A difficulty with the earlier embodiments (Figures 2, 4, 6 and 8), can be understood by considering Figure 11. Reflected light must make two passes through the colour filters 82, whereas (white) light transmitted from the backlight 96 makes only a single pass through each colour filter 82. In order to achieve a satisfactory brightness level in reflection it is necessary to use wide band colour filters 82, which let through a wide range of light frequencies. However, this results in a lower colour saturation. That is, reflected light from the LCD appears whiter in colour to the observer 20. The problem is worse for transmission, because transmitted light makes only a single pass through the colour filters 82, and the colour saturation is therefore lower.

The light throughput and high resolution capability in the transmissive mode can be improved in the following way. Instead of coating each micro colour filter 82 continuously and evenly over the pixel area, each micro colour filter 82 can be provided with a transparent region, and the remainder of the area of the micro colour filter 82 can be made more absorbing (ie. more narrow band). For example, for the green micro colour filters 82, the remainder of the micro colour filter 82 can be made more green, so that in the reflective mode no change is perceived by the observer 20 because the transparent region is compensated for by the "more green" region. The same can be done for the red and blue micro colour filters 82. An advantage is achieved in the transmission mode because the transparent regions transmit light of any colour, and thus every micro colour filter 82 is better adapted to transmit light from any of the coloured LEDs 102, 104 and 106.

If the liquid crystal is provided with partially reflecting electrodes having transmissive areas, the transmissive areas can be optically aligned with said transparent regions. A black and white (greyscales) embodiment is also possible, which does not use differently coloured filters and backlights.

Figure 13 shows the electrooptic response of the embodiment of Figure 12. The transmission results are shown by curve 120, and the reflection results by curve 122. The results below about 1.6V are not useful, as the liquid crystal cannot be used for fast

switching in this region. The display 100 should therefore be used in the range 1.6V to 5V.

Figure 14 shows the wavelength dependence of the electooptic response of the embodiment of Figure 12. The transmission and reflection results when the display 100 is switched to the "on" state are shown by curves 124 and 126 respectively. The transmission and reflection results when the display 100 is switched to the "off" state are shown by curves 128 and 130 respectively. It will be seen from these results that the wavelength dependence is reasonably flat over the wavelengths of interest (ie from blue to red).

It should be appreciated that whilst the second aspect of the invention, relating to a time sequential transflective display using differently coloured flashing backlights can be used in conjunction with the first aspect of the invention, it is not so limited. In particular, the second aspect of the invention can be used with any transflective display.

CLAIMS

1 A transflective liquid crystal display comprising a liquid crystal cell disposed between a front substrate and a rear substrate, a front polariser located in front of the front substrate and a rear polariser located behind the rear substrate, a front retarder located between the front substrate and the front polariser, a rear retarder located between the rear substrate and the rear polariser, and a light source located behind the rear polariser.

2 A transflective display as claimed in claim 1 wherein the front retarder is an achromatic combination retarder.

3 A transflective display as claimed in claim 1 or 2, wherein the front retarder comprises a front halfwave plate and a front quarterwave plate.

4 A transflective display as claimed in claim 3, wherein the front quarterwave plate has a retardation that, in conjunction with the retardation of the liquid crystal layer, produces in one state circular polarised light after a single pass.

5 A transflective display as claimed in claim 3 or 4, wherein the front quarterwave plate has a retardation that, in conjunction with the retardation of the liquid crystal layer, produces in a second state linear polarised light after a single pass.

6 A transflective display as claimed in claim 3, 4 or 5, wherein the front quarterwave plate has a retardation of between 0nm and 250nm.

7 A transflective display as claimed in any preceding claim, wherein the rear retarder comprises a rear quarterwave plate.

8 A transflective display as claimed in claim 7, when also dependent, directly or indirectly, on claim 3, wherein the rear quarterwave plate has a retardation that, in

conjunction with the retardation of the liquid crystal layer and the front quarterwave plate, produces in one state circular polarised light after a single pass.

9 A transflective display as claimed in claim 7 or 8, when also dependent, directly or indirectly, on claim 3, wherein the rear quarterwave plate has a retardation that, in conjunction with the retardation of the liquid crystal layer and the front quarterwave plate, produces in a second state linear polarised light after a single pass.

10 A transflective display as claimed in claim 7, 8 or 9, wherein the rear quarterwave plate has a retardation of between 100nm and 180nm.

11 A transflective display as claimed in any preceding claim, wherein the rear substrate is provided with a partially reflective and partially transmissive mirror.

12 A transflective display as claimed in any preceding claim, wherein the liquid crystal cell is provided with a rear electrode which is partially reflective and partially transmissive.

13 A transflective display as claimed in any preceding claim, wherein the rear retarder further comprises a rear halfwave plate.

14 A transflective display as claimed in claim 13, when also dependent directly or indirectly on claim 6, wherein the rear halfwave plate is located between the rear quarterwave plate and the rear polariser.

15 A transflective display comprising a liquid crystal divided into a plurality of pixels, addressing means for addressing each pixel and switching each pixel between different states resulting in different levels of transmission of light through the display, a flashing backlight located behind the liquid crystal, and a partially reflective mirror located between the liquid crystal and the backlight for both reflecting ambient light back through the liquid crystal and allowing transmission of light from the backlight through

the liquid crystal, wherein each pixel is provided with a light filter, and wherein the backlight comprises a plurality of sequentially flashing light sources.

16 A transflective display as claimed in claim 15, wherein each light filter is a colour light filter, and wherein said sequentially flashing light sources are of different colours.

17 A transflective display as claimed in claim 15 or 16, wherein said liquid crystal is part of an active matrix display.

18 A transflective display as claimed in claim 15, 16 or 17, wherein the liquid crystal forms a Pi or OCB cell.

19 A transflective display as claimed in any one of claims 15 to 18, wherein each light source is a light emitting diode (LED).

20 A transflective display as claimed in any one of claims 1 to 19, wherein each colour filter provides a varying level of absorption across its area.

21 A transflective display as claimed in claim 20 wherein each colour filter has a transparent region.

22 A transflective display as claimed in claim 21, wherein said liquid crystal is provided with a plurality of partially reflective electrodes each having a light transmissive area, and wherein each said transmissive area is optically aligned with a transparent region of one of said colour filters.

23 A transflective display as claimed in any one of claims 15 to 22, which also has any or all of the features of the transflective display of claims 1 to 14.

24 A transflective display substantially as hereinbefore described with reference to any of Figures 2, 4, 6, 8, 11 or 12.

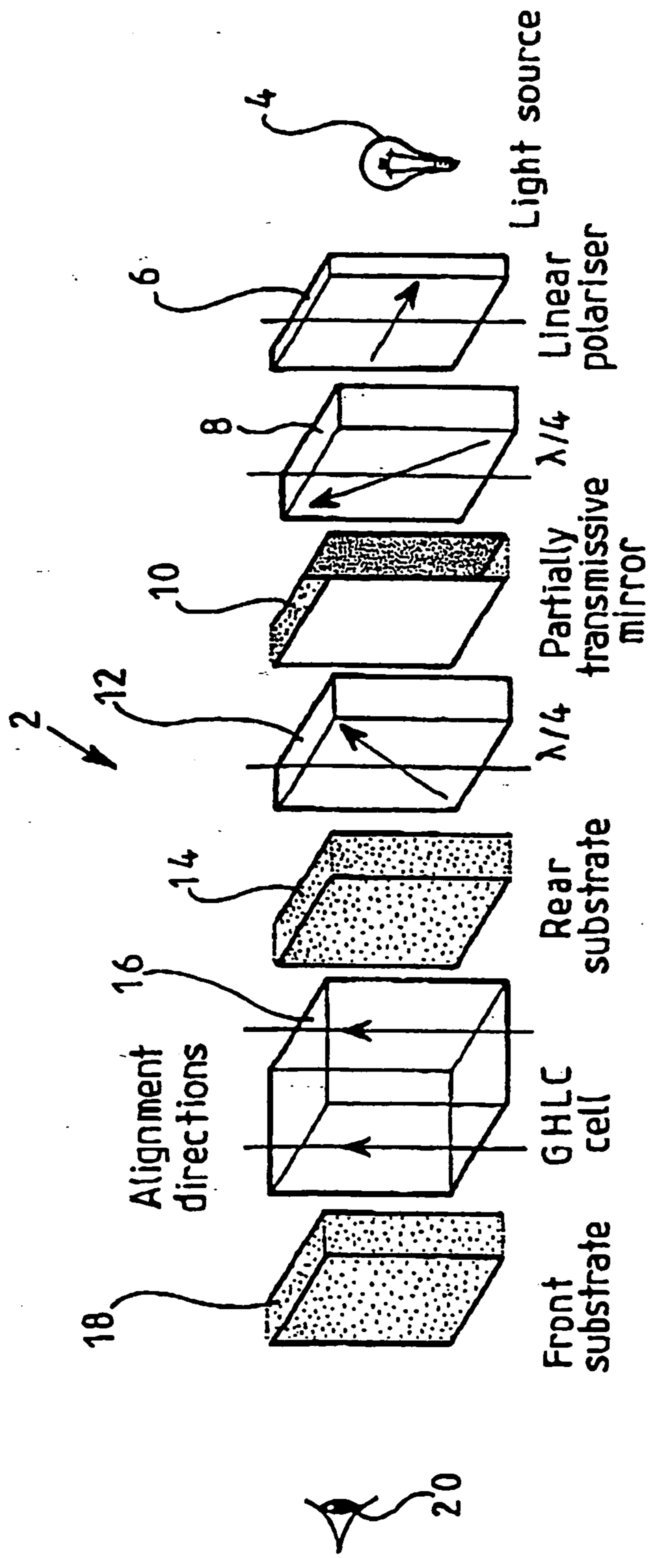

Light source
4
6
Linear polariser
8
λ/4
10
Partially transmissive mirror
12
λ/4
2
14
Rear substrate
16
Alignment directions
GHLC cell
18
Front substrate
20

FIG 1

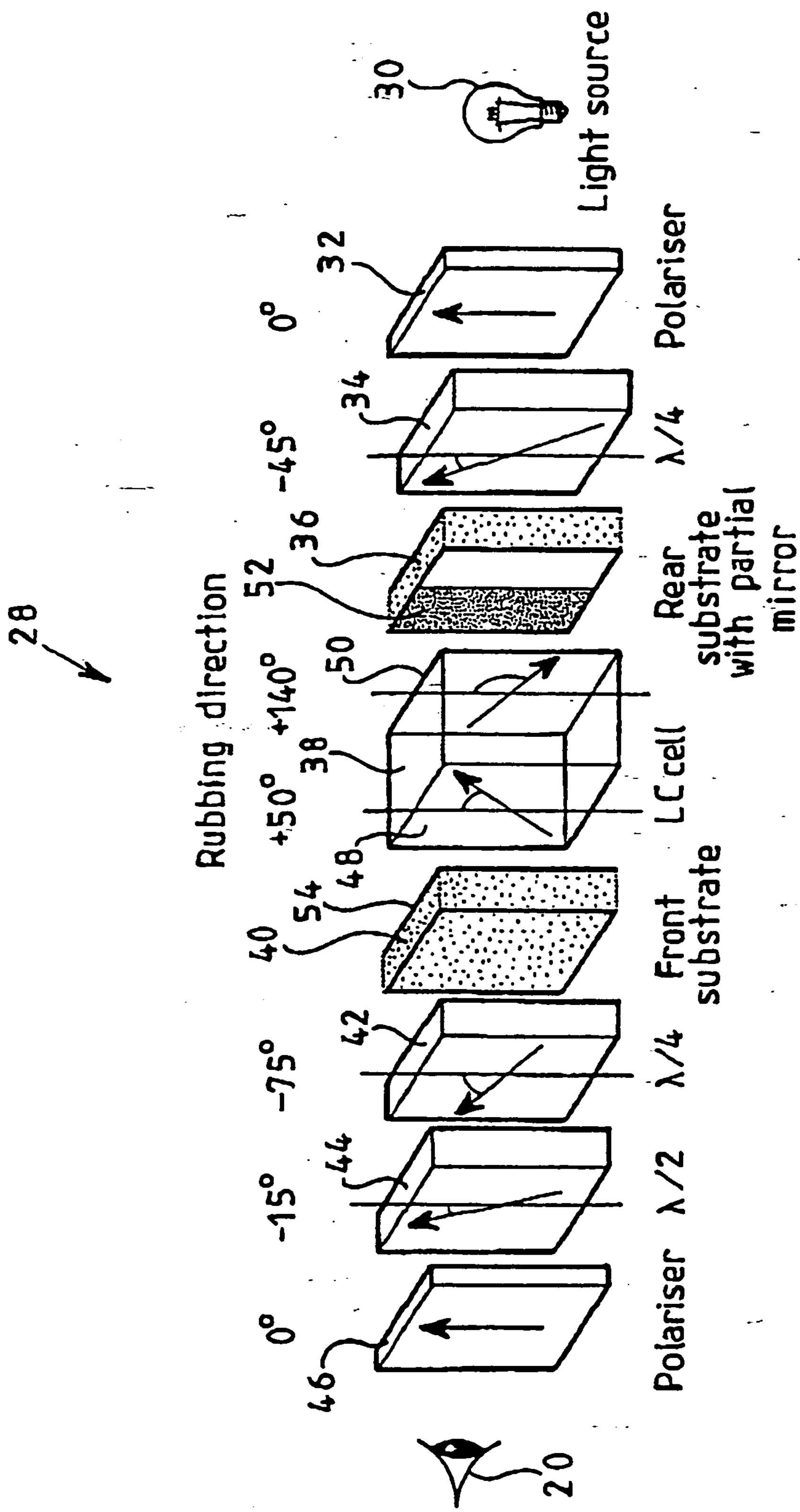

28
Rubbing direction
Light source
30
0°
32
Polariser
-45°
34
λ/4
36
52
Rear substrate with partial mirror
+140°
50
+50°
38
48
LC cell
40
54
Front substrate
-75°
42
λ/4
-15°
44
λ/2
0°
46
Polariser
20

FIG 2

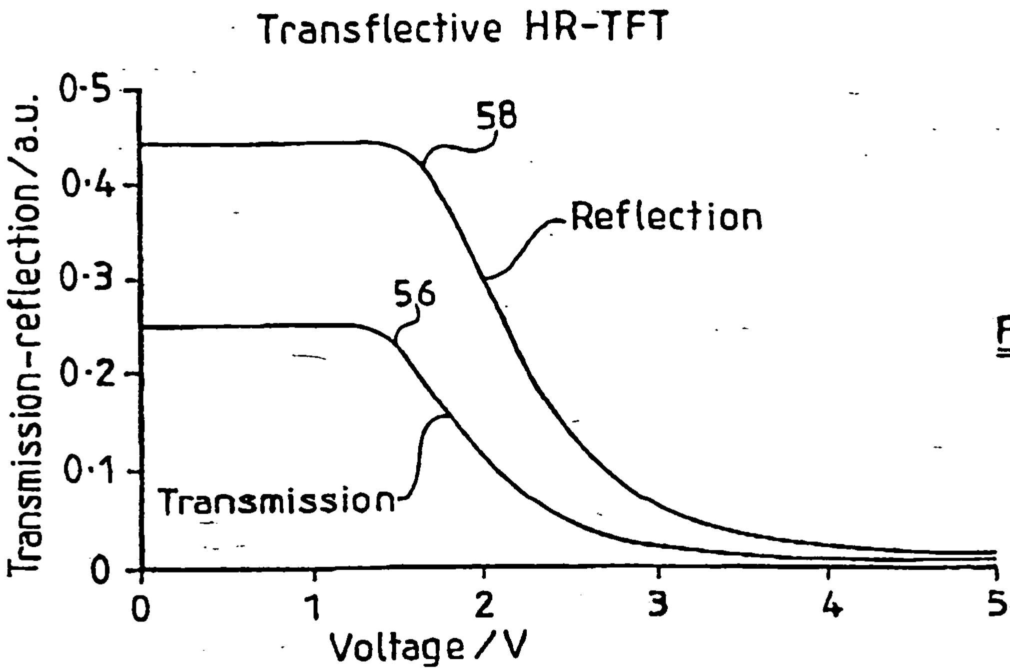

Transflective HR-TFT
0·5
0·4
0·3
0·2
0·1
0
Transmission-reflection/a.u.
58
Reflection
56
Transmission
0
1
2
3
4
5
Voltage/V

FIG 3

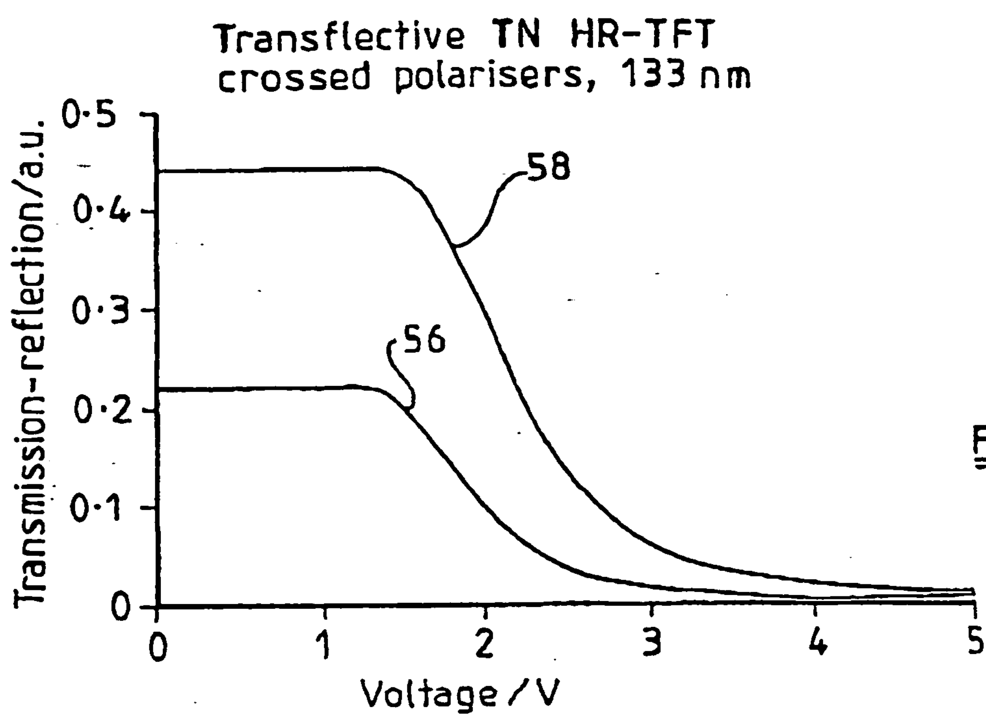

Transflective TN HR-TFT
crossed polarisers, 133 nm
0·5
0·4
0·3
0·2
0·1
0
Transmission-reflection/a.u.
58
56
0
1
2
3
4
5
Voltage/V

FIG 3a

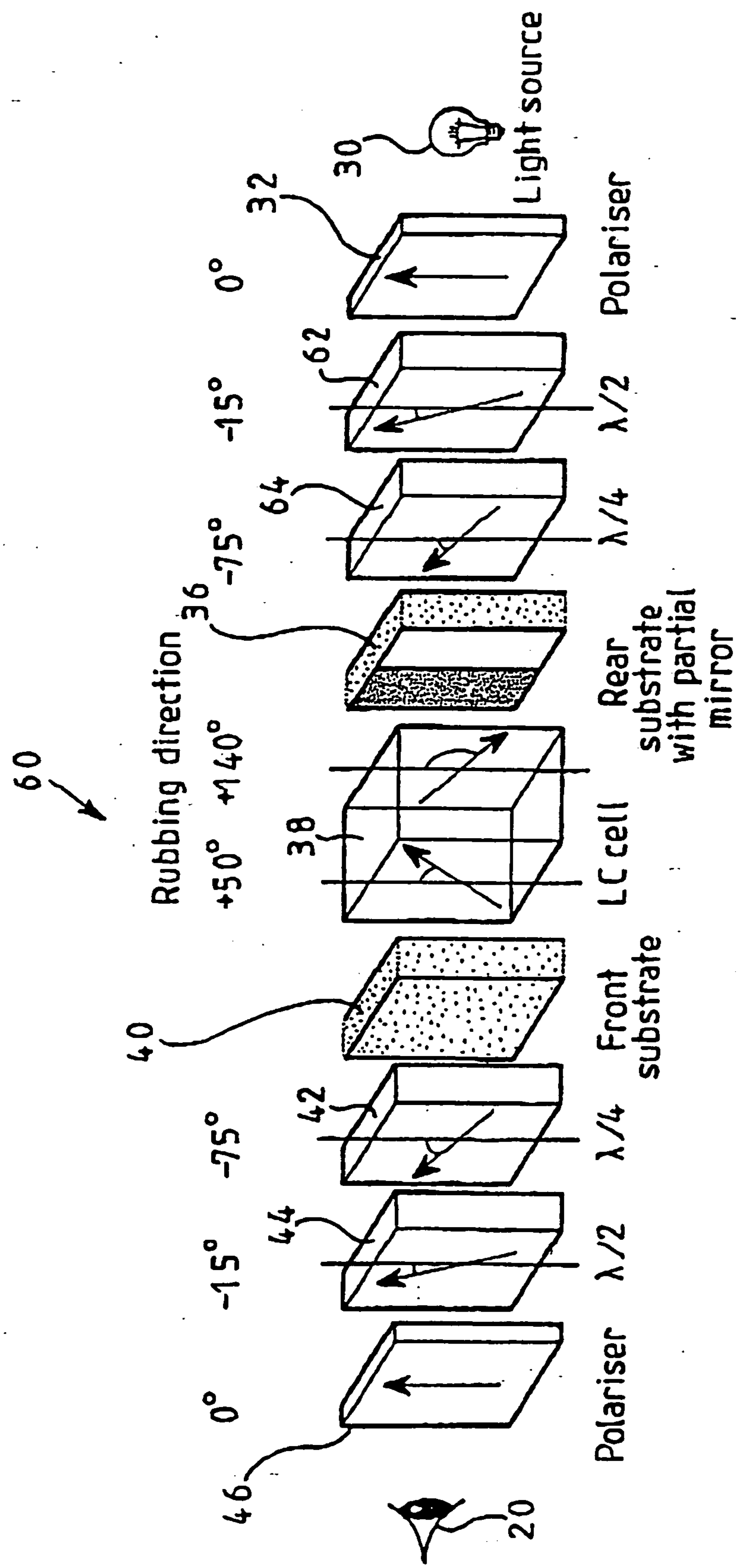

60
Rubbing direction
+50° +140°
0°
-15°
-75°
-75°
-15°
0°
30
Light source
32
Polariser
62
λ/2
64
λ/4
36
Rear substrate with partial mirror
38
LC cell
40
Front substrate
42
λ/4
44
λ/2
46
Polariser
20

FIG 4

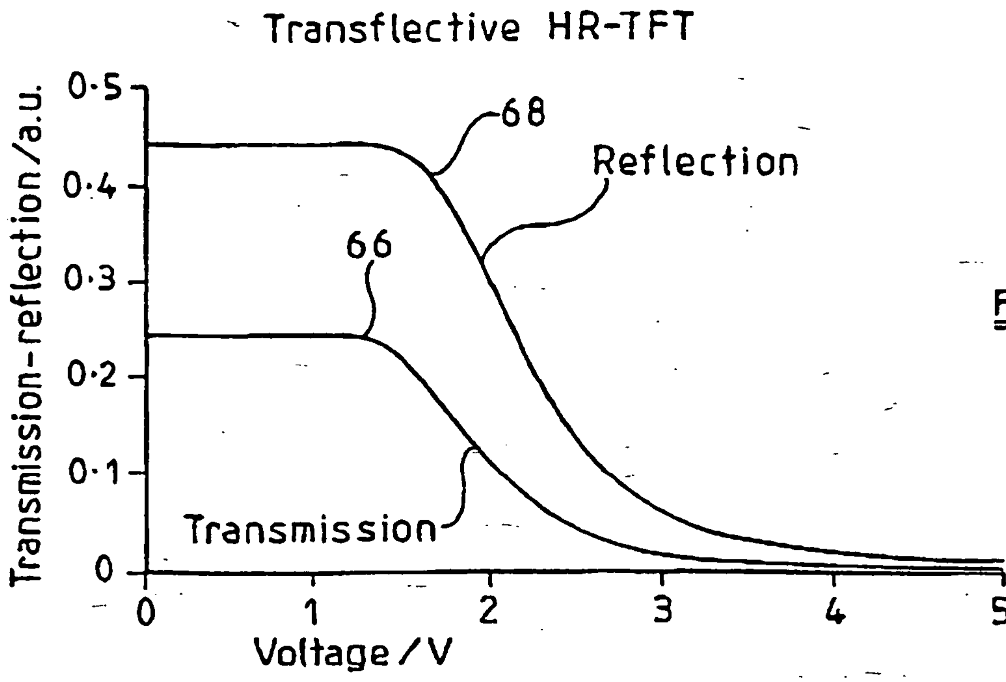

Transflective HR-TFT
Transmission-reflection/a.u.
0·5
0·4
0·3
0·2
0·1
0
68
Reflection
66
Transmission
0
1
2
3
4
5
Voltage / V

FIG 5

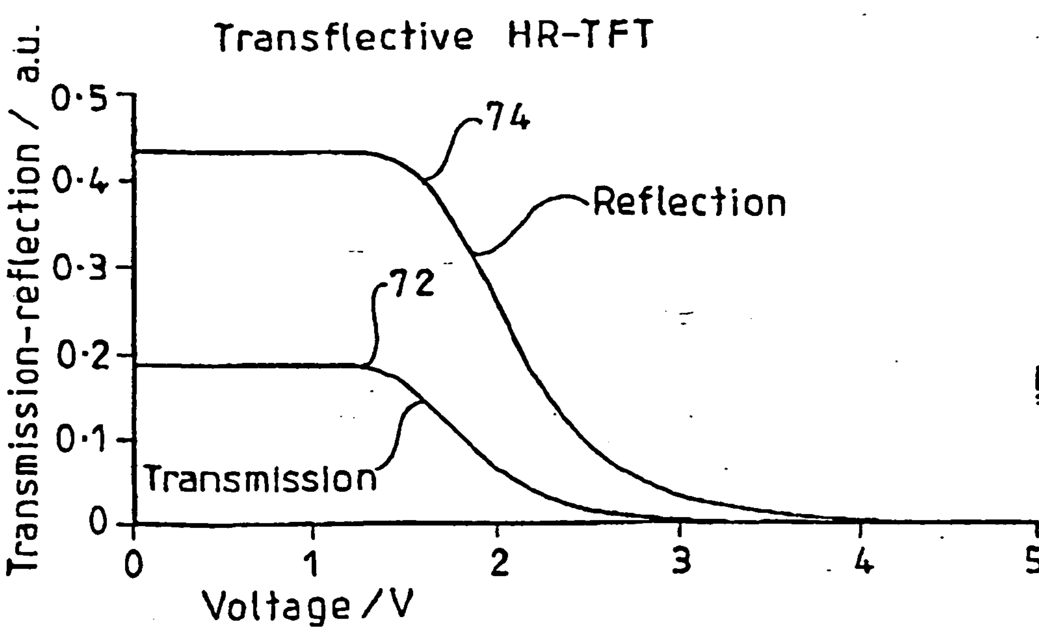
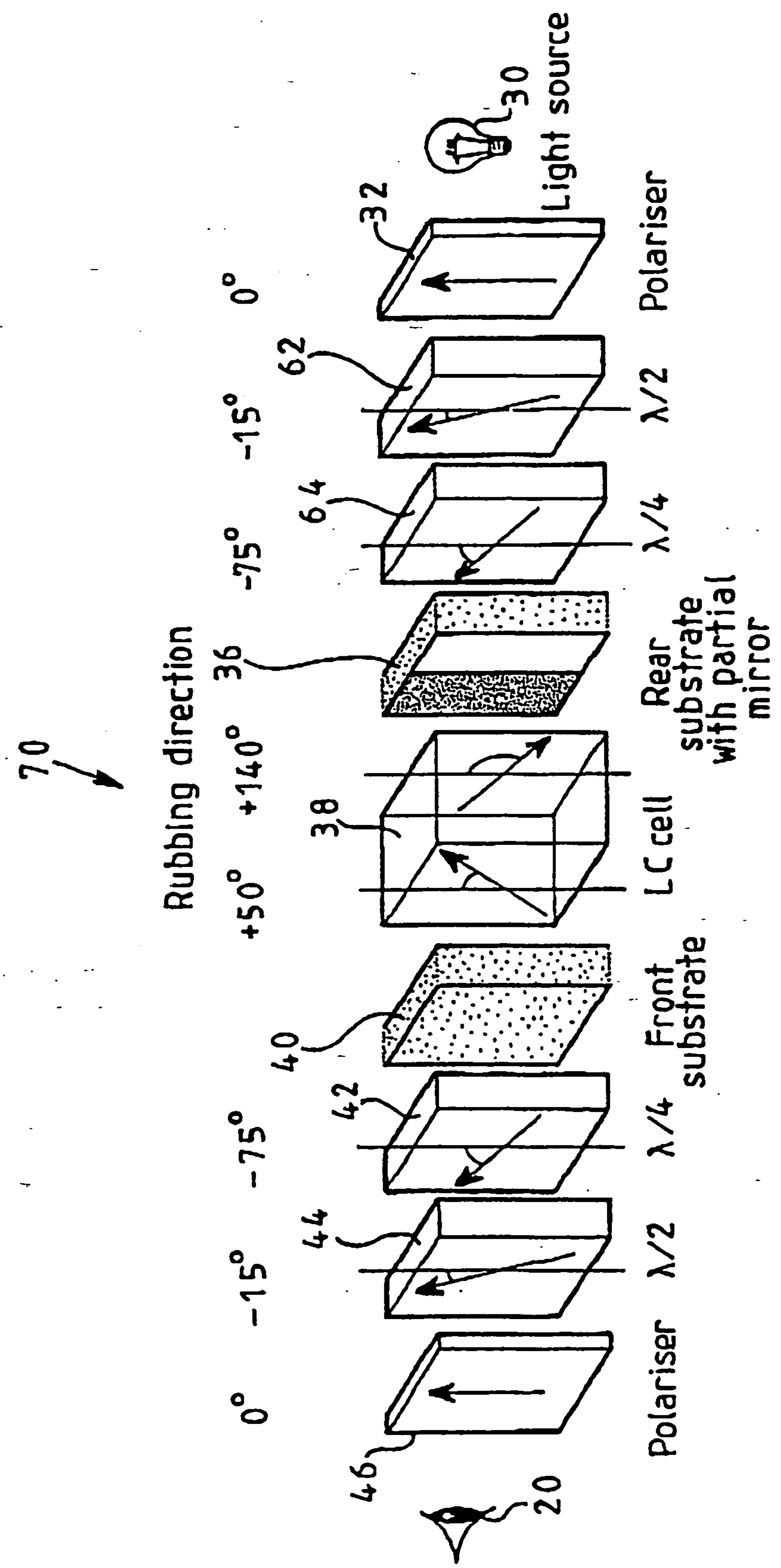

Transflective HR-TFT
Transmission-reflection / a.u.
0·5
0·4
0·3
0·2
0·1
0
74
Reflection
72
Transmission
0
1
2
3
4
5
Voltage / V

FIG 7



30
Light source
32
Polariser
0°
62
λ/2
-15°
64
λ/4
-75°
Rubbing direction
36
Rear substrate with partial mirror
70
+140°
+50°
38
LC cell
40
Front substrate
42
λ/4
-75°
44
λ/2
-15°
0°
Polariser
46
20

FIG 6

Transflective TN HR-TFT
crossed polarisers, 144 & achr. 133nm

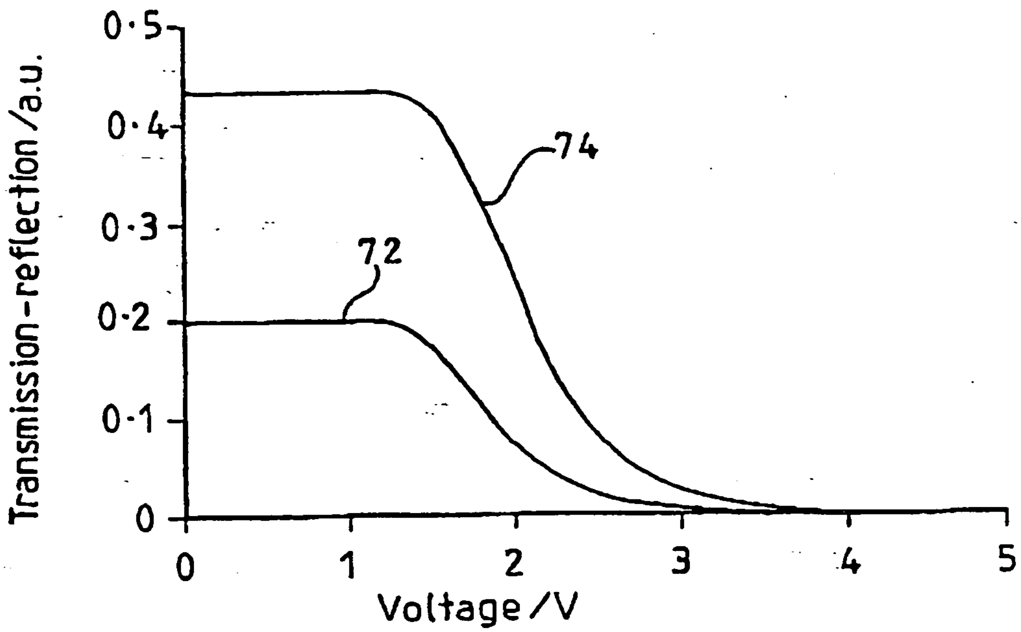


FIG 7a

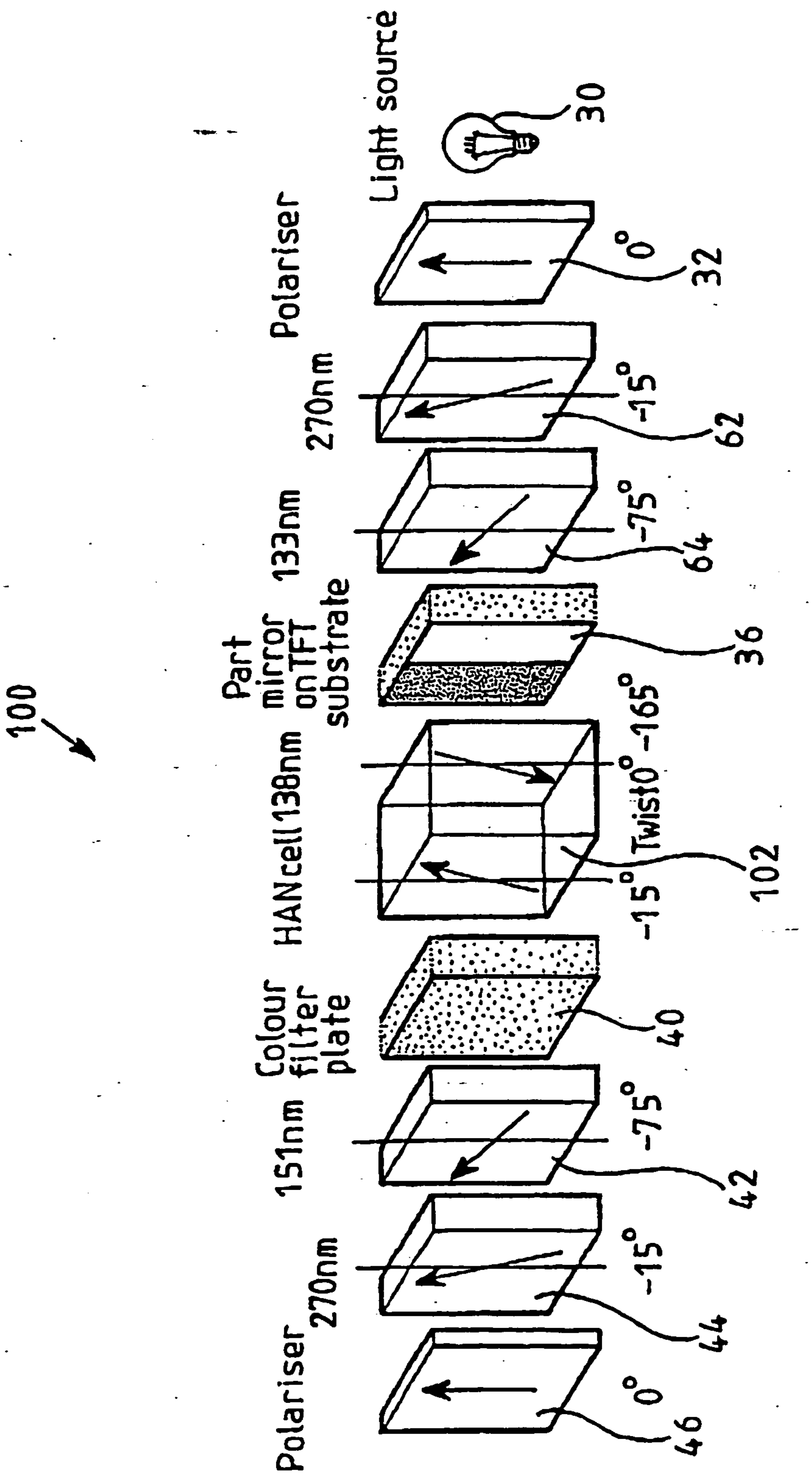

100
Light source
30
Polariser
0°
32
270nm
-15°
62
133nm
-75°
64
Part mirror on TFT substrate
36
HAN cell 138nm
Twist 0° -165°
-15°
102
Colour filter plate
40
151nm
-75°
42
270nm
-15°
44
Polariser
0°
46

FIG 8

Transflective HAN HR-TFT
parallel polarisers

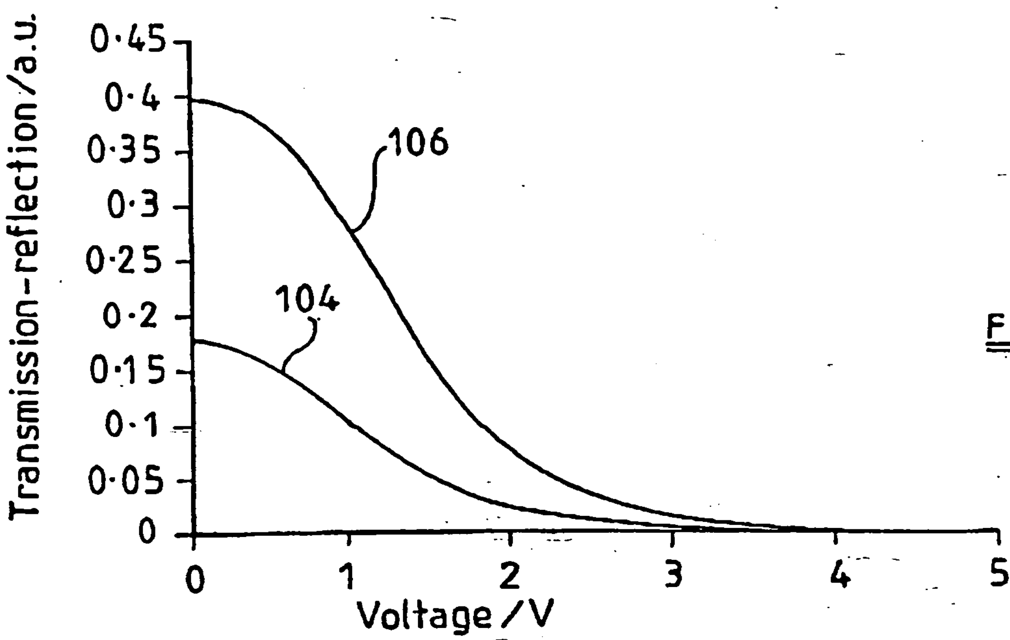


FIG 9

Transflective HAN HR-TFT
crossed polarisers

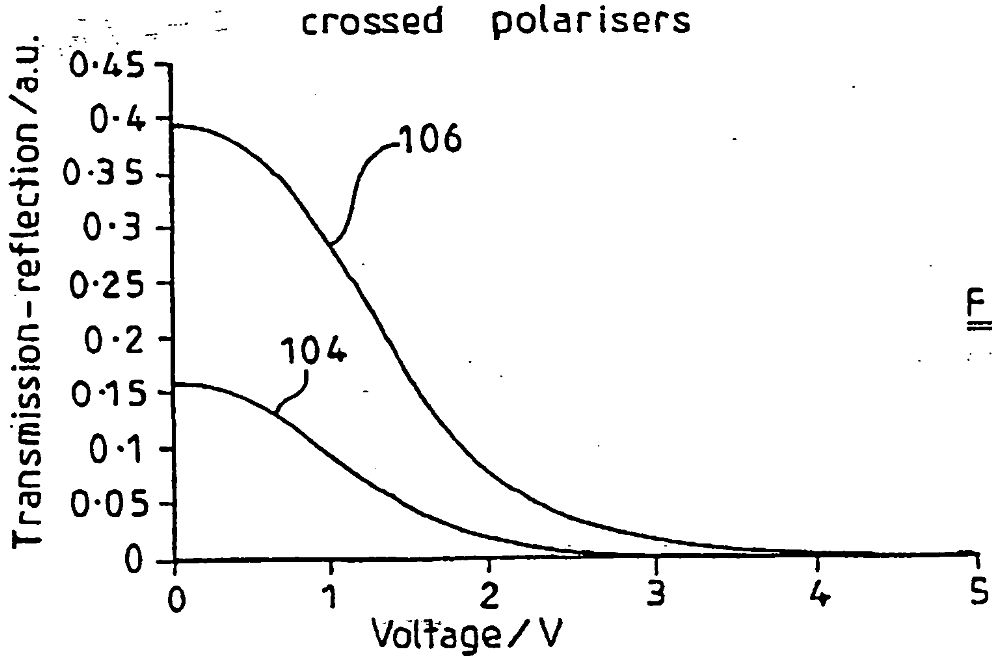


FIG 9a

FIG 10

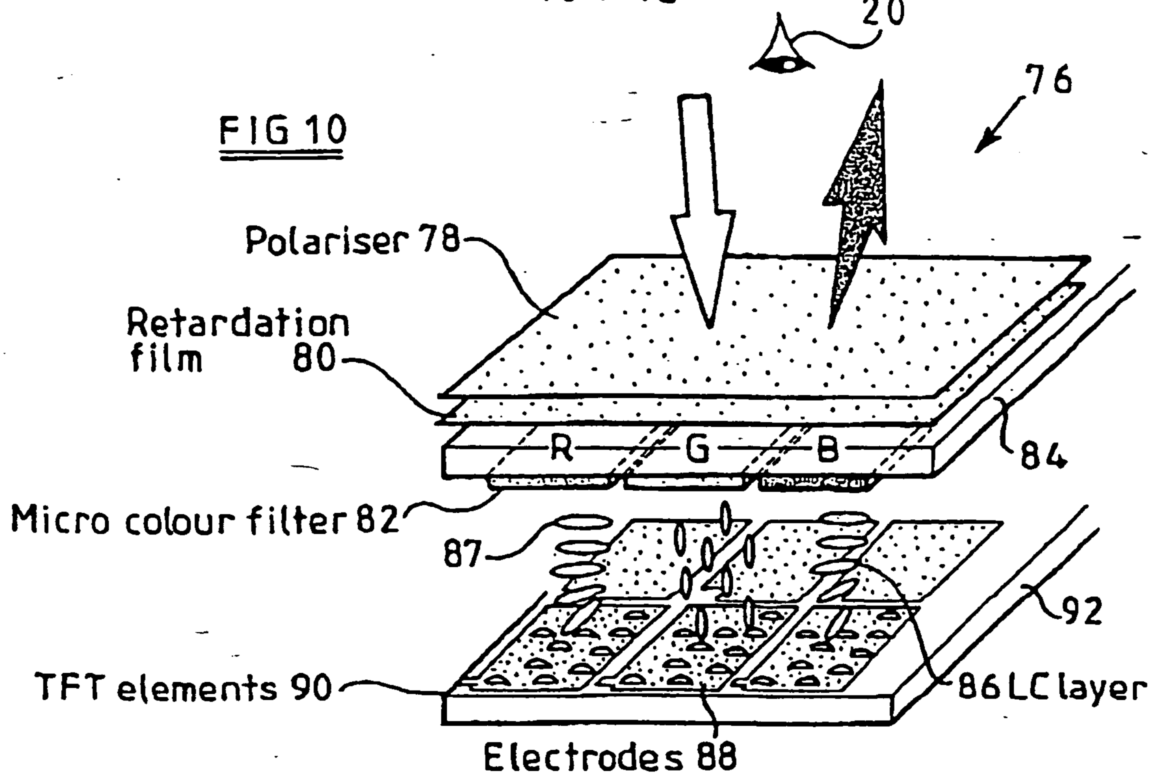
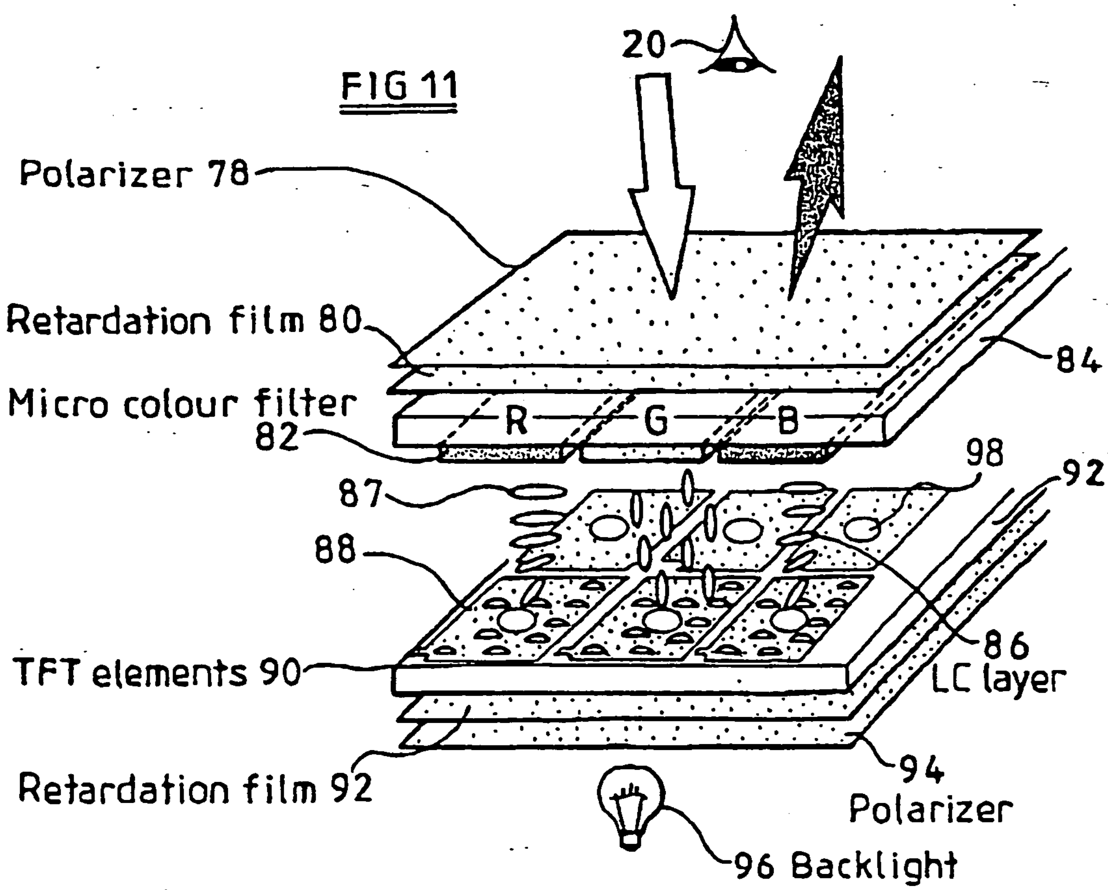

20
76
Polariser 78
Retardation film 80
R
G
B
84
Micro colour filter 82
87
92
TFT elements 90
86 LC layer
Electrodes 88

FIG 11


20
Polarizer 78
Retardation film 80
84
Micro colour filter 82
R
G
B
98
92
87
88
86
LC layer
TFT elements 90
Retardation film 92
94
Polarizer
96 Backlight

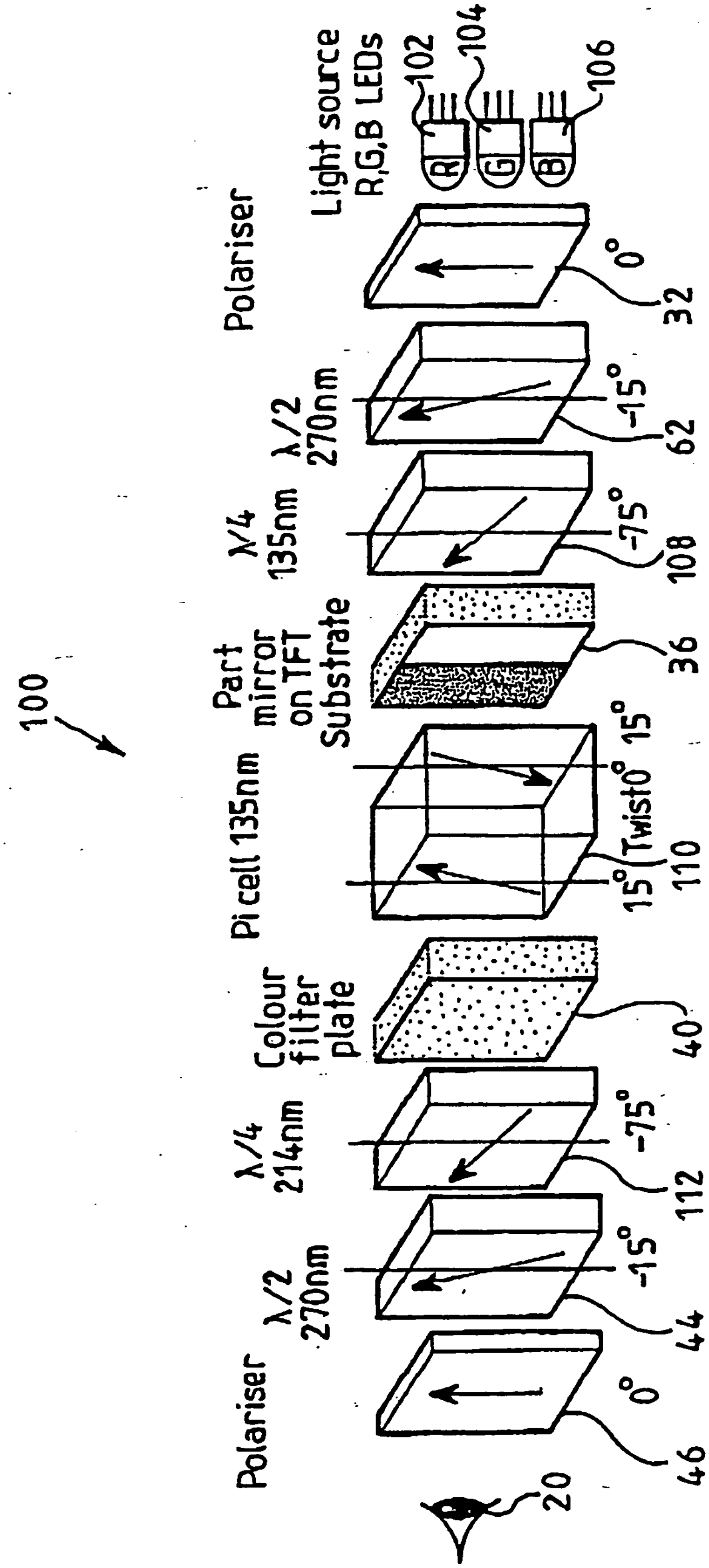

Light source
R,G,B LEDs
102
104
106
R
G
B
Polariser
0°
32
λ/2
270nm
-15°
62
λ/4
135nm
-75°
108
Part
mirror
on TFT
Substrate
36
Pi cell 135nm
15°
Twist0°
15°
110
100
Colour
filter
plate
40
λ/4
214nm
-75°
112
λ/2
270nm
-15°
44
Polariser
0°
46
20

FIG 12

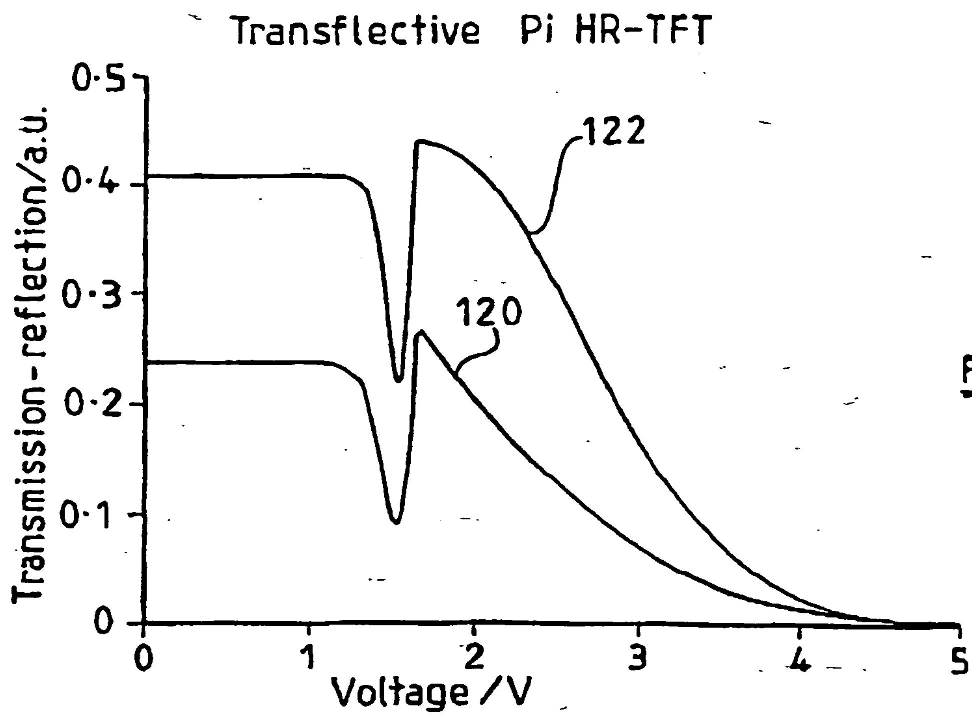

Transflective Pi HR-TFT
Transmission-reflection/a.u.
0·5
0·4
0·3
0·2
0·1
0
122
120
0
1
2
3
4
5
Voltage/V

FIG 13

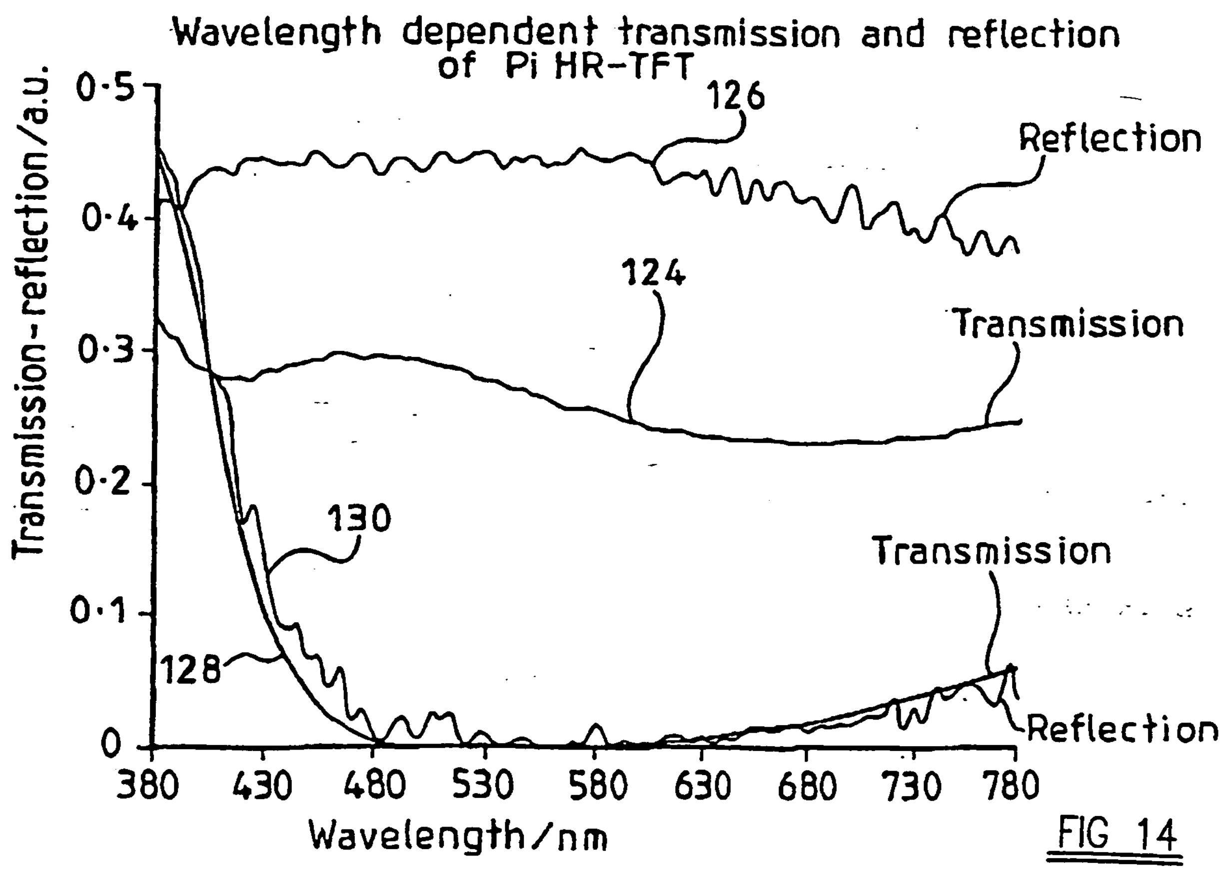

Wavelength dependent transmission and reflection of Pi HR-TFT
Transmission-reflection/a.u.
0·5
0·4
0·3
0·2
0·1
0
126
Reflection
124
Transmission
130
128
Transmission
Reflection
380
430
480
530
580
630
680
730
780
Wavelength/nm

FIG 14